International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

National Conference on Recent Advances in Civil Engineering Infrastructure (rACEi-2021)

Identification of Groundwater Recharge Potential Zones of Hyderabad Region using Analytical Hierarchy Process in Arcgis

Veerendra Gopi K*, Rajesh M^, Shirisha K^

*Assistant Professor, Department of Civil Engineering, VNR Vignana Jyothi Institute of Engineering &Technology, Hyderabad, India
^Graduate student, Department of Civil Engineering, VNR Vignana Jyothi Institute of Engineering &Technology, Hyderabad, India

Received 05 Aug 2021, Accepted 10 Aug 2021, Available online 15 Aug June 2021, **Special Issue-9 (Aug 2021)**

Abstract

The integration of Geographic Information System (GIS) and remote sensing (RS) has become a refinement in the field of groundwater research. As every year, water demand is increasing rapidly, which indicates that there will be more water demand for groundwater resources because the source of surface water is no longer to meet the demand. In the present study, an effort was made to delineate the groundwater recharge potential zones for the Hyderabad city using Analytical Hierarchy Process (AHP) in Arc GIS by incorporating remote sensing data. The various thematic layers (lineament density, land use and land cover, drainage density, slope, and geomorphology) were prepared using remote sensing data. The normalized weights of these layers were calculated using analytical method of AHP pair wise matrix. The ranks and weightages obtained from AHP were given in the weighted overlay analysis tool of ArcGIS to find the recharge potential zones. As a result, the groundwater recharge potential zones map was generated and categorized into five classes, namely very high, high, moderate, low, and very low based on the specified parameters. The regions categorized under best are considered as the best regions for ground water recharge. The groundwater recharge potential zone map will be useful to implement suitable recharge methods to increase the groundwater levels.

Keywords: *Remote sensing, Geographic Information System, Analytical Hierarchy Process, Weighted overlay analysis.*

1. Introduction

Groundwater is the massive available resource of fresh water found below the ground and significant source for various uses such as domestic, industrial and for irrigation. Depletion of groundwater is a long – term declination, caused due to continuous underwater pumping. Due to rapid development and urbanization, declining of water table causes shallow wells to dry up. Because of the massive construction activity, the foundation work which is distributed throughout the study area is the main reason for the decline of groundwater levels. Which has direct impact in rainwater percolation. In 21st century, water security is expected to be the biggest challenge (Snyder, 2019). Groundwater table in the study area (Hyderabad) is going down rapidly as the extraction rate is high. Therefore, finding potential groundwater recharge areas is integral to sustainable management and planning of the city's water resource (Kulkarni et al, 2018). GIS is an effective tool for planning and managing groundwater issues because it gives lot of information in less time. RS & GIS techniques were found to be easier for handling, processing and data storage compared to other usual methods. For finding potential groundwater recharge areas GIS is a quick and cost-effective platform with the interaction of hydrological, geological, and atmospheric factors (Ghosh et al., 2015). GIS has been used in groundwater studies and numerous studies have been conducted to find potential groundwater recharge areas using RS and GIS methods in different regions.

Analytical Hierarchy Process (AHP) first developed by Saaty in 1980 and used as a multi-criteria decision-making technique in the field of water resources engineering. Multi-criteria decision making identified as an effective decision-making tool for the problem involving various influencing factors as in the earlier study (Chenini, et al, 2010). The mathematical complexity of decision making decreased significantly with the AHP method which assigns levels from low to high based on the influence between parameters influencing the groundwater potential zone (Devanantham, et al, 2020; Kaliraj. S, et al, 2013).

2. Study area

Hyderabad is the capital of Telangana state in South India that sits on the Deccan Plateau, between 17.37°N and 78.48°E. In the fastest growing metro cities, Hyderabad is one among them. Residual hills, Pedi

Plains, and valley fills are the three primary topographical units. The Musi River runs from west to east, with a 2 m/km slope, and most rivers are naturally transitory. In Hyderabad, the Musi River is the primary river. This river originates in the Anantagiri hills in the Vikarabad region of Ranga Reddy district and runs for 70 kilometers before joining the Osman and Himayat Sagar lakes in Hyderabad. The study region receives an average yearly rainfall of 810 mm. Population of Hyderabad city has increased with a growth rate of 8.2 % from 2002 to 2015 (census 2011, Govt. of India). From 2002 – 2015, urban built-up area observed a maximum positive change from 41.35 % to 62.87 % at an expansion rate of 4.01 km^2/year (Srikanta S, et al, 2017). During the summer the temperature may reach 45°C, but in June with arrival of monsoon, the temperature reduces to 38°C to 26°C. Hussain Sagar, Mir Alam tank, Afzal Sagar, Jalpalli, Ma-Sehaba Tank, Talab Katta, Osmansagar and Himayatsagar, Saroor Nagar Lake are among the natural and artificial lakes in Hyderabad.

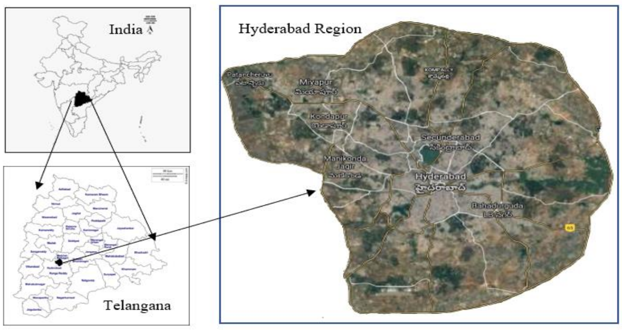

Fig. 1 Study area of Hyderabad city around outer ring road

3. Methodology and data used

3.1 Data collection

Data sources required for the study are specified below. The thematic maps required for the study area were extracted from various sources and digitized and preprocessed using GIS tools. Five thematic maps opted in the present study are geomorphology, land use land cover, slope, drainage density and lineament density. Soil and geology thematic maps are also considered to be influencing factors in groundwater recharge. But are not considered in the present study because the soil map obtained from Food and Agricultural Organization (FAO) and geology map obtained from geological survey of India displayed a single type of feature in the study area.

1) The base map of the study area was taken from the google maps and digitized in ArcGIS.
2) Cartosat Digital Elevation Model (DEM) data with a resolution of 30 m X 30 m on a global scale are available through USGS earth explorer.
3) Geomorphology map was downloaded from Geological survey of India in the shapefile format.
4) Land use land cover data for Hyderabad was downloaded from USGS earth explorer.
5) Lineament map was obtained from NRSC Bhuvan portal.

3.2 Methodology

The method adopted for the study is shown in figure 2. Cartosat DEM was delineated using the georeferenced boundary shape file for the study area in ArcGIS 10.5. Drainage density map was prepared using the stream pattern and line density spatial analyst tool. Geomorphology map for the study location was digitized from Telangana state geomorphology map. Lineament density map was prepared for the study using line density tool in ArcGIS. Digitized layers extracted for the study were transformed to raster data using the feature to raster tool in ArcGIS. All the digitized layers were resampled into similar cell size 30 m X 30 m using nearest neighborhood technique

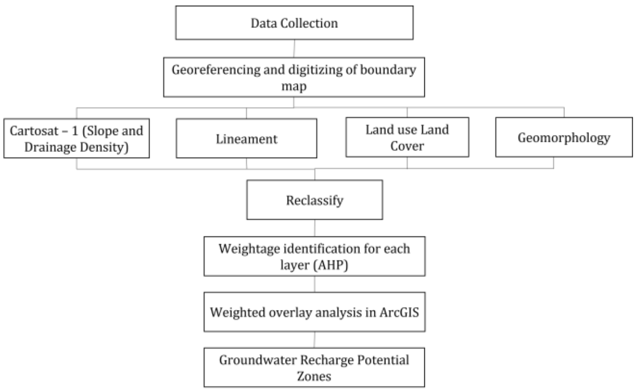

Fig. 2 Methodology flow chart

3.3 Preparation of thematic maps

Slope map:

It is a significant terrain characteristic which expresses the steepness of the ground surface. Surface runoff and rate of infiltration are influenced by the slope of the surface. A higher slope results in rapid runoff and limits the potential for recharging. The slope map was developed using Cartosat DEM, and represented in terms of percentage, using the 'slope' function in ArcGIS. It was further reclassified into different classes using the reclassification option in the spatial analysis tool. Ranks have been assigned to each layer on the slope map. Low percentage of the slope was assigned with highest rank as it implies high amount of infiltration.

Drainage density:

Drainage density is an expression of the proximity of spacing channels, providing a quantitative measurement of river length, within an area in km/km2. Due to increased surface runoff, the high-density area is not feasible for groundwater enhancement. Drainage density map was prepared from DEM map using line density spatial analyst tool.

Lineament density:

Lineaments are structurally controlled linear or curvilinear features. Lineaments represent the zones of faulting and fracturing resulting in increased secondary porosity and permeability. They provide the pathway for groundwater movement. The areas with high lineament density are good for groundwater recharge potential zones. The line density tool in the spatial analysis tool was used to transform the lineament map to lineament density map.

Geomorphology:

Geomorphology refers to the study of the physical features of the earth's outer surface and represents the landforms and topography of a region. Geomorphology is one of the main factors used widely for the delineation of groundwater recharge potential zones. Different geomorphology classes were assigned different ranks based on their influence on groundwater recharging conditions.

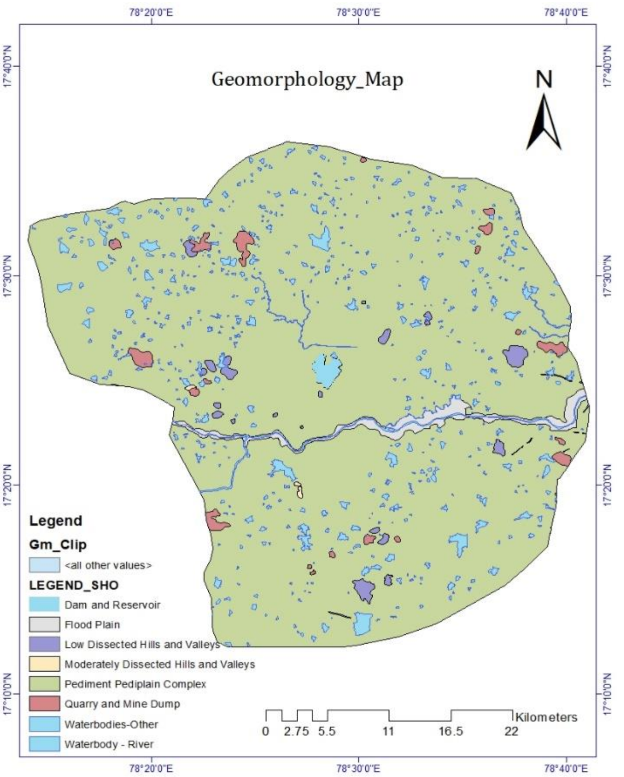

Fig. 3 Geomorphology map of the study area

Land use & land cover:

Land cover plays a vital role in the development of ground water resources. It controls many hydrogeological processes in the water cycle such as seepage, surface runoff and so on. Land use land cover is reflecting the human influence on the groundwater resource and provides its indication on groundwater requirements. The clipped map for the study area was then reclassified. Different ranks were assigned to different layers of land use and land cover classes based on their influence on groundwater recharge potential. Built up area is provided with least rank because of less infiltration and water bodies and vegetation are provided with higher ranks.

Each thematic map is reclassified and assigned appropriate weights according to multi criteria decision making technique of analytical hierarchy process (AHP). The potential groundwater recharge zone map is determined by overlaying all thematic maps using the spatial analysis tool according to the weighted overlay method in ArcGIS.

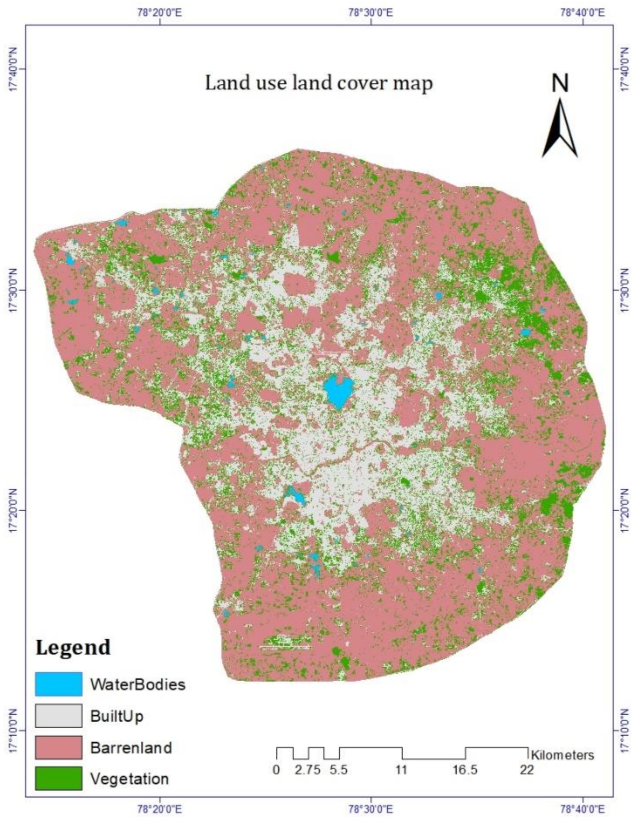

Fig. 4 Land use land cover map of the study area

Analytical Hierarchy Process (AHP):

In this study, the AHP approach was used to integrate different thematic layers according to the weights assigned for appropriate selection. AHP process is stated as extensive technology which integrates subjective and practical opinions of experts in decision making by assessing several factors (Sener et al, 2011). The relative importance of each layer is determined with Saaty's, 1–9 scale, where a score of 1 represents equal importance and a score of 9 indicates the extreme importance (Saaty, 2006). Principal eigen value and consistency index of the AHP process specifies the concept of uncertainty in decision making (Saaty 2006). Saaty provided Consistency Index (CI) as a measure of consistency specified in equation 1.

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (1)$$

Where, λ_{max} is the largest eigen value of the pair wise comparison matrix and n is the number of factors. Consistency Ratio (CR) which is a measure of consistency of pair wise comparison matrix is given by equation 2.

$$CR = \frac{CI}{RI} \quad (2)$$

where RI is the Ratio Index.

RI value is directly taken from Saaty, 1980 research paper based on number of classes. If the value of CR is less than 0.1 the inconsistency is acceptable, otherwise there is need to revise the subjective judgement. Pair wise comparison matrix along with normalized weights for each thematic layer identified based on CR < 0.1 are provided in table 1.

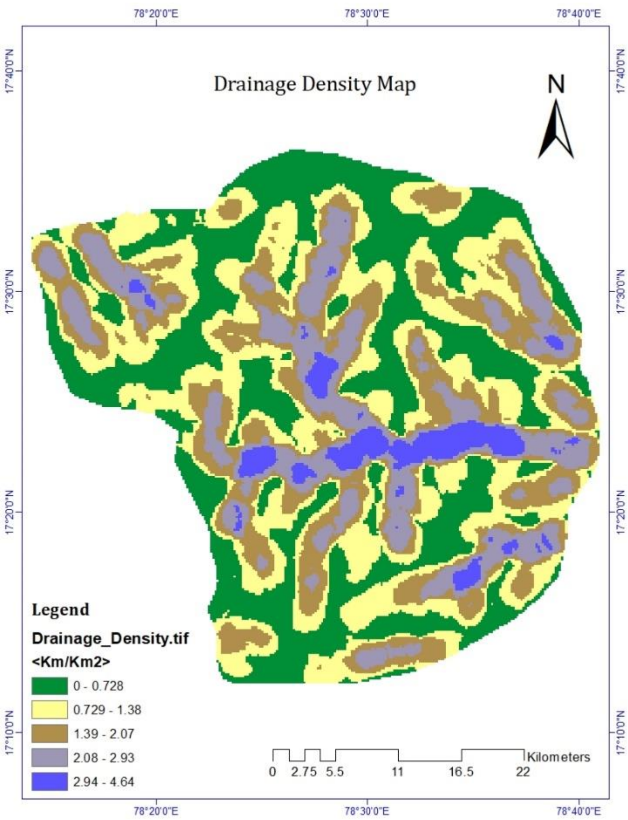

Fig. 5 Drainage density map of the study area

4. Results

Weights and ranks allocated to each thematic layer in the weighted overlay analysis of ArcGIS for identification of groundwater potential zones are specified in table 2.

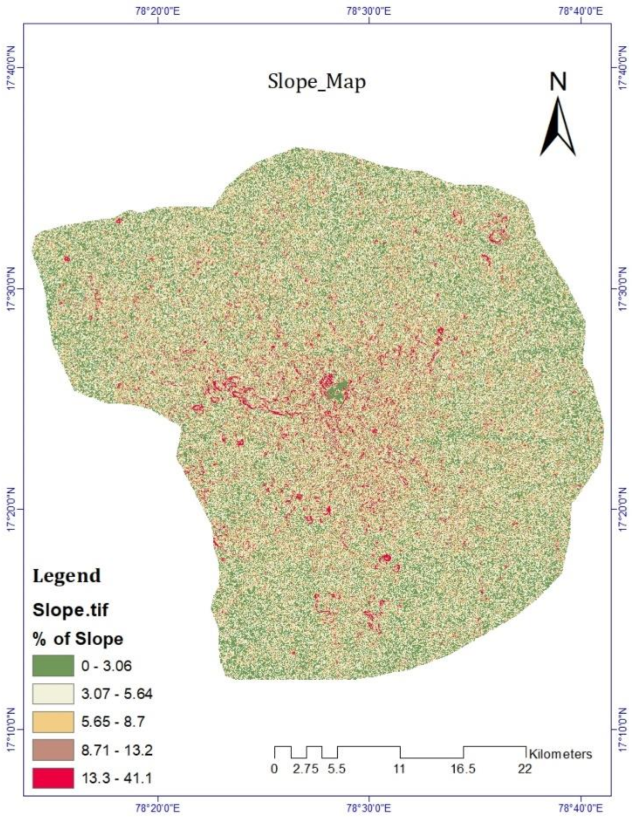

Fig 6. Slope map of the study area

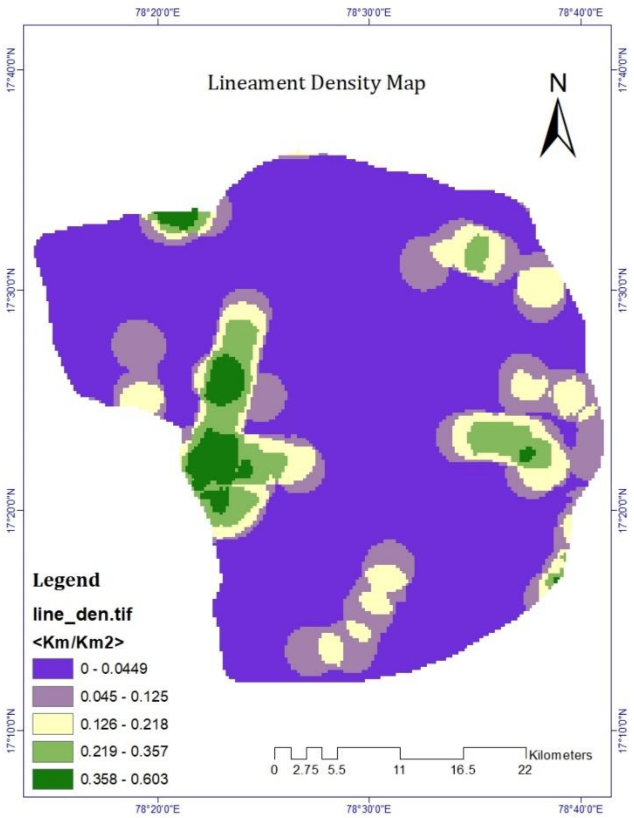

Fig 7. Lineament density map of the study area

Figure 3 explains various geomorphology features in the study area. The pediment pediplain complex covers most of the study area. Water bodies, flood plains and pediment pediplain complex contribute for more infiltration and hilly dissected area's contribution for infiltration is minimal. As per the figure 4, built up area is maximum because the selected study area is Hyderabad city. Possibility of percolation in built up areas at minimum and rank was assigned as 1. High rank was assigned to water bodies as they contribute for maximum recharging. Drainage density scale from figure 5 indicates that drainage density is aligned towards the Musi river in the center region of the Hyderabad. Smaller density scale implies more chances of recharging. Higher rank is assigned for 0 - 0.728 km/km² and least rank to 2.94 – 4.64 km/km². Percentage of slope for the study area indicated in figure 6 is changing from 0 – 3.06 to 13.3 – 41.1. High implies more runoff and less infiltration. Slope scale 13.3 – 41.1 is assigned rank 1 and 0 – 3.06 is assigned with highest rank. Lineament density map shown in figure 7, specifies study area is having a greater number of fractures in west, northwest, and southeast regions in terms of km/km². Density scale of 0.358 – 0.603 km/km² is assigned with highest rank as it implies greater possibility of groundwater recharging.

Table 1: Pair wise comparison matrix and normalized weights of five thematic maps

Theme	Land use land cover	Geomorphology	% Slope	Drainage density	Lineament density	Normalized weights
Land use land cover	1	2	3	5	7	0.42
Geomorphology	0.5	1	3	4	6	0.30
% Slope	0.33	0.33	1	3	4	0.16
Drainage density	0.2	0.25	0.33	1	3	0.08
Lineament density	0.14	0.17	0.25	0.33	1	0.04

Table 2 Weighted factors influencing recharge

S. No.	*Parameters*	*Classes*	*Ranking*	*Weightage (%)*
1	Geomorphology	Dams and Reservoir Flood Plain Low Dissected Hills and Valleys Moderately Dissected Hills and Valley Pediment Pediplain Complex Quarry and Mine Dump Waterbodies – others Waterbodies – rivers	5 4 1 2 4 3 5 5	30
2	Drainage density (km/km²)	0 – 0.728 0.729 – 1.38 1.39 – 2.07 2.08 – 2.93 2.94 – 4.64	5 4 3 2 1	8
3	Land use & land cover	Water bodies Built-up area Barren land Vegetation	5 1 2 4	42
4	Lineament density (km/km²)	0 – 0.0449 0.045 – 0.125 0.126 – 0.218 0.219 – 0.357 0.358 – 0.603	1 2 3 4 5	4
5	Slope (%)	0 – 3.06 3.07 – 5.64 5.65 – 8.7 8.71 – 13.2 13.3 – 41.1	5 4 3 2 1	16

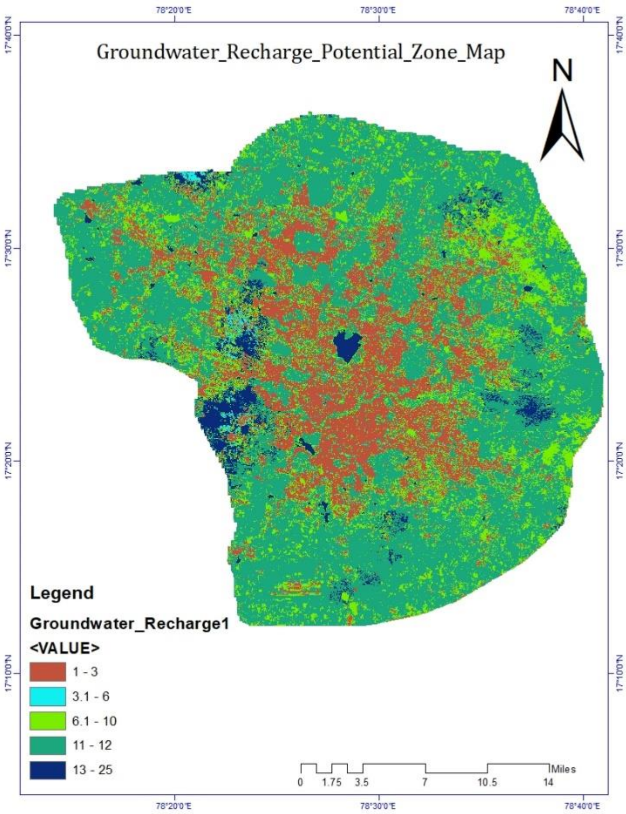

Fig 8. Groundwater recharge potential zone map of study area

All the thematic layers were transformed into raster format and reclassified using reclassify tool in ArcGIS. AHP weightages for each layer were provided in weighted overlay analysis to identify the groundwater recharge potential zones for Hyderabad around outer ring road. Figure 8 displays the possible locations for implementation of groundwater recharging methods. High groundwater potential is identified in west region with more lineament density 0.358 – 0.603 km/km2, gentle slope and low drainage density. Obtained potential zone map was classified into appropriate

Table 3 Classification of groundwater potential zones

S. No.	Groundwater recharge potential range	Groundwater prospective
1	1 – 3	Very high
2	3.1 – 6	High
3	6.1 – 10	Moderate
4	11 – 12	Low
5	13 – 25	Very low

classes namely very high, high, moderate, low, and very low potential as specified in table 3.

Conclusion

The present study focuses on identification of groundwater recharge potential zones in Hyderabad region around outer ring road. Mapping of potential zones using RS techniques and AHP was the main objective. Thematic layers considered for the study are geomorphology, land use land cover, drainage density, slope, and lineament density. Good recharge potential zones are identified at locations with high lineament density, low drainage density and with high pediment pediplain complex. Effective methods need to be implemented in the regions identified with low recharge potential. Results obtained in the research would suggest for implementation of best management practices like infiltration galleries, recharge pits and rainwater harvesting to maintain sustainability in groundwater management.

References

I. Chenini, A. B. Mammou,M. El May, (2010), Groundwater recharge zone mapping using GIS-based multi-criteria analysis: a case study in Central Tunisia (Maknassy Basin), *Water Resour. Manag*, 24 (5), 921–939.

Devanantham Abijith, Subbarayan Saravanan, Leelambar Singh, Jesudasm Jacinth Jennifer, Thiyagarajan Saranya, Parthasarathy. K. S. S, (2020), GIS based multi criteria analysis for identification of potential groundwater recharge zones – a case study from Ponnaniyaru watershed, Tamil Nadu, India, *HydroResearch 3*, 2589-7578, doi.org/10.1016/j.hydres.2020.02.002

Hadi allafta, Christian Opp, Suman Patra, (2020), Identification of groundwater potential zones using remote sensing and GIS techniques: A case study of the Shatt Al-Arab Basin, *Journal of Remote Sensing,* doi.org/10.3390/rs13010112

H. Kulkarni, Uma Aslekar, Siddharth Patil, (2018), Groundwater management in India: status, challenges and a framework for responses, *Springer Hydrogeology,* doi.org/10.1007/978-981-10-3889-1_36, 36, 615 – 642

H. D. Bhave, Y. B. Katpatal, A. M. Pophare, (2019), Identification of groundwater recharge potential zone for watershed using GIS and remote sensing, *International journal of advanced research in engineering and technology,* 10, 121-135

K. Niranjan Kumar, A.G. S. Reddy, R. Mallikarjuna Reddy, K. Srinivas Varma, (2009), Preliminary investigations of groundwater quality in Hyderabad city, Andhra Pradesh, *International Journal of Chemical Science*, 7(1), 59-70

K. Venkatesh, M. Vani, (2018), Urban sprawl and sustainable development in Hyderabad: A geoinformatics approach, *International Journal of Creative Research Thoughts*, 6, 285-294

Makhmudov K, Yasuhiro Mitani, Tetsuya Kusuda, (2015), Forecasting groundwater level in an arid area according to climatic data, *Journal of water resource and protection,* 7, 553-560

Mohanavelu Senthilkumar, Devadasan Gnanasundar, Rethinam Arumugam, (2019), Identifying groundwater recharge zones using remote sensing & GIS techniques in Amaravathi aquifer system, Tamil Nadu, South India, *J. Sustainable Environment Research,* doi.org/10.1186/s42834-019-0014-7

N. Sundarajan, S. Sankaran, (2019), Groundwater modelling of Musi basin Hyderabad, India: a case study, *Applied Water Science,* 10:14, 1-22, doi.org/10.1007/s13201-019-1048-z

Prasanta Kumar Ghosh, Sujay Bandyopadhya, Narayan Chandra Jana, (2015), Mapping of groundwater potential zones in hard rock terrain using geoinformatics: a case of

Kumari watershed in western part of West Bengal, *Model Earth Systems and Environment, Springer, doi* 10.1007/s40808-015-0044-z

Soumendra N Bhanja, M. Abhijit, R Rangarajan, Bridget R. Scanlon, M. Pragnaditya, Shubha Verma, (2019), Long-term groundwater recharge rates across India by in situ measurements, *Hydrology and Earth System Science,* doi.org/10.5194/hess-23-711-2019, 23, 711–722

S. Venkatcharyulu, Ravinder Rathod, Y. Kamala Raju, (2020), Evaluation of groundwater quality of Bhachupally, Nizampet and Pragathinagar village, *E3S Web of Conferences, ICMED 2020,* doi.org/10.1051/e3sconf/202018401105, 184

Status of groundwater level scenario, (2019), *Groundwater Department, Government of Telangana*

S. Kaliraj, N. Chandrasekar, N. S. Magesh, (2013), Identification of potential groundwater recharge zones in Vaigai upper basin, Tamil Nadu, using GIS based analytical hierarchical process (AHP) technique, *Arab Journal of Geosciences,* DOI 10.1007/s12517-013-0849-x

S. K. Goyal, B. S. Choudary, O. Singh,G. K. Sethi, P. K. Thakur, (2010), Variability analysis of groundwater levels-A GIS based case study, *Journal Indian Society Remote Sensing,* 38, 355-364

Snyder. S, (2019), Water In Crisis - Spotlight India, *https://thewaterproject.org/water-crisis/water-in-crisis-india*

S. Srikanta, Shwetha Jain, Somnath Sen, Sandeep Bhatt, (2017), Urban heat island intensity and its mitigation strategies in the fast grown urban area, *Journal of urban management,* doi: 10.1016/j.jum.2019.09.004

Thomas L. Saaty and Luis G. Vargas, (2006), Decision making with the analytical network process, *Springer science*

Y. Siva Prasad, B. Venkateswara Raa, (2017), Groundwater depletion and groundwater balance studies of Kandivalasa river basin, Vizianagram district, Andhra Pradesh, India, *Groundwater for sustainable development,* 6, 71-78